

DEVELOPING SUSTAINABLE RENEWABLE ENERGY MARKETS IN MEXICO:

RESULTS AND FUTURE CHALLENGES

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ABSTRACT

This paper characterizes the accomplishments and future challenges of the Mexico Renewable Energy Program, sponsored by the U.S. Department of Energy (DOE) and the U.S. Agency for International Development (USAID), and managed by Sandia National Laboratories. The goals of the Mexico Renewable Energy Program are to promote the use of renewable energy technologies (RETs), promote environmental sustainability, enhance economic and social development in Mexico, create new business opportunities for the renewable energy (RE) industry, and offset greenhouse gas emissions. The program is focused on rural, off-grid, productive-use RE applications, particularly photovoltaic (PV), small wind, and solar thermal systems. Since the inception of the successful Mexico Program, more than 300 kW of RE power, representing more than 400 RE systems, have been installed. These systems induced additional interest that led to replication by other users. All of these systems were installed through partnerships with in-country organizations such as the Fideicomiso de Riesgo Compartido (FIRCO), Grupo de Trabajo de Energía Renovable (GTER) de Chihuahua, and local partners of the World Wildlife Fund, Conservation International, and The Nature Conservancy. While implementing these projects, the supply network for rural RE systems has been strengthened, while potential and real customers of these suppliers have gained a better appreciation of the value of RETs. As the Mexico RE Program continues its shift from pilot project implementation to replication of its successes, the program team is developing new opportunities and is facing new challenges. Several Mexican government programs are at varying stages of preparation that will build on and broaden the program. Successful implementation of these new efforts will require significant planning and execution of training activities, promotion, and technical oversight. For these challenges to be met and for these programs to be successful, continued productive collaboration among partner organizations will be required.

INTRODUCTION

Throughout Mexico, RETs are utilized in a wide variety of manners to help meet energy needs on both local and regional scales. From the large grid-connected geothermal, and hydro plants to the small remote PV home lighting systems, these technologies are providing direct benefits to millions of people across Mexico. In some cases, the industries for these technologies are well established and growing at a steady rate, such as solar water heating in the Mexico City area. In others, however, problems exist in the delivery chain and with user and supplier expectations that seriously limit the growth of these industries. A recent study estimated that the potential market for rural applications of RETs is more than \$US1 billion – more than half of that in the area of water pumping for

agriculture [1]. Continued institutional development and strengthening is needed for these markets to fully realize their potential.

Since 1994, Sandia National Laboratories has managed a successful program in Mexico to develop markets for rural, productive-use applications of RETs. This program is sponsored by USAID and DOE. The goals of the program are to increase the appropriate and sustainable use of RETs, thereby expanding markets for U.S. and Mexican industries. RETs are used as a tool for economic development, environmental protection, and in combating global climate change. The program model has these key tenets, listed below [2]:

- Establishment of strong local partnerships;
- Capacity building with partners, suppliers, and end-users;
- Provision of technical assistance;
- Implementation of sustainable pilot projects;
- Continued monitoring and evaluation of project and program impacts; and
- Encouraging replication through follow-on public and private sector activities.

As Sandia and its partners have worked to develop and refine this model, many challenges have been met along the way, while new challenges surface. The key to the success of the Sandia program in Mexico has been a dedicated team that works to appropriately match rural development needs with quality RETs that cost-effectively meet these needs.

PARTERSHIPS

When the Mexico RE Program was formally launched in 1994, it was decided that the program team would focus on productive-use applications of RETs in already funded, on-going programs. Productive uses are those that provide economic benefits to the users of the systems, such as water pumping for livestock or lighting for carpentry and sewing workshops, and allow a means to pay for the associated capital costs. Because of the economic benefits that productive-use installations provide to end-users, local equipment suppliers have taken a strong interest in working with Sandia to grow their markets in this area. There are also additional environmental benefits, such as promoting PV water pumping systems to existing ranches and wells for fixed herd sizes that promote sustainable ranch management practices. The program has since broadened its focus to include innovative delivery mechanisms for home PV lighting systems and water purification. The success of the program is based on the establishment of strong partnerships between the experienced Sandia renewables team and Mexican partner organizations

interested in utilizing RETs within their existing development programs.

In the agriculture sector, Sandia has teamed with several state and federal organizations involved in agricultural development and has worked to introduce RETs into their regular program activities. The primary partner organization is the Fideicomiso de Riesgo Compartido (FIRCO), under the Secretariat of Agriculture (SAGAR). Through this national organization which has offices in every state, Sandia has assisted in the installation of more than 200 PV water-pumping systems for livestock and small-scale irrigation in 15 Mexican states. Based on these activities, FIRCO has succeeded in making RETs an explicit component of the Alianza para El Campo program, based on a \$US400 million World Bank loan, that focuses on increasing the productivity of ranches through modernization techniques. This new policy has greatly increased access for ranchers to RE systems, while improving sustainable ranching practices, and has been an important success for the program.

Sandia has also encouraged inter-agency collaborations within Mexico, such as having FIRCO work with COTECOCA, a Mexican agency that develops ranch grazing indexes based on local conditions to promote sustainable ranching practices. This allows for more efficient use of water and land resources over traditional practices. All ranch related PV water pumping projects have had to meet COTECOCA guidelines on herd size based on the sustainable local range grazing capacity. The PV water pumping system is sized for an optimal herd size, and unlike a gasoline powered system, the rancher cannot increase herd size above this sustainable maximum since the PV water pump provides a fixed amount of water each day. Overall, PV is used to help protect the environment while increasing ranch profitability and reducing O&M costs.

In the state of Chihuahua, the Sandia team has assisted in the development of a RE working group (GTER), which consists of representatives from more than a dozen State and Federal government agencies, non-profit organizations, and academic institutions. This working group is developing innovative means of implementing projects under the program. In addition to the installation of more than 50 PV ranch and community water pumping systems, there have been water pumping and water purification systems installed for rural Tarahumara indigenous communities. GTER has also implemented Mexico's first end-user financing program for RETs. Thus far, more than 145 PV home lighting systems have been financed and installed, as well as 16 systems for productive use applications. This financing program is the first such model in Mexico for financing RETs.

Sandia has also developed strategic partnerships in the Protected Areas Management sector. Working with the World Wildlife Fund, The Nature Conservancy, Conservation International, and their local partner organizations, Sandia has identified and developed RE applications to facilitate the management of reserves and protected areas. Other projects with these partners have focused on the economic development of the communities that buffer Mexican reserves. More than 65 independent systems have been installed through these partnerships, primarily in the southern states of Chiapas, Oaxaca, and Quintana Roo. These projects meet a variety of energy needs. For instance, PV-powered communications systems in Chiapas are helping rural coffee growers to be more responsive to market demands and receive better prices for their products. In Oaxaca and Chiapas, radio systems are key factors in the suppression and early control of forest fires. Other uses include facilities power for ranger's quarters and biological research stations, water pumping for visitor's centers and communities, and outdoor lighting systems.

Figure 1 shows the distribution of technologies and applications that have been implemented with in-country partners through the

Sandia program. To date, more than 400 RE systems have been installed through the program, primarily in agricultural applications (livestock water pumping and small-scale irrigation); protected areas management (facilities power for ranger and research stations, communications, water pumping, etc.); and rural electrification (many independent home systems and one central community system).

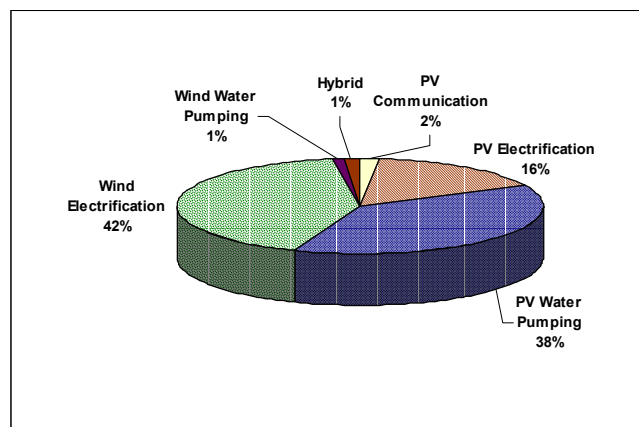


Figure 1. Technologies and applications of projects based on 250 kW installed capacity for the Mexico Program.

Perhaps the greatest challenge in the development of these projects has been that these partners did not traditionally consider energy needs in their planning activities, and thus the potential value of RETs was largely unknown. This is especially true in the case of the protected area projects, where often-small gasoline generators or automobile batteries are purchased as an afterthought – both of which carry potential health and environmental risks. In the case of water pumping for ranches and remote communities, it is often the lack of a local energy supply (i.e., electric grid or access to diesel fuel) that keeps a project from moving forward. When the program was initiated, there existed little institutional capacity within Sandia's original partner organizations to develop and procure RE projects.

Sandia has worked closely with partner organizations to assist them with implementing pilot projects through their own institutional mechanisms. The Sandia team has directly procured less than 5% of the pilot systems, all of which have been used in intensive professional training exercises. Partner organizations and end-users have purchased all other systems, with Sandia sharing the costs by varying percentages. By coupling the purchase of RE equipment with capacity building exercises – both formally and informally, ranging from workshops and seminars to detailed technical reviews of vendor proposals – the partners have learned to include RETs in their programmatic activities. They have also developed realistic expectations of RETs and the capacity to relay those expectations to local suppliers and be sure that they are met. Sandia continues to reach out to new Mexican partners to break down these same type of barriers.

Capacity building exercises have been a key ingredient in the success of the Mexico RE Program. Working with in-country partners and suppliers, the program team has conducted over 50 seminars and workshops. Over 2,000 engineers, technicians, and decision makers representing over 150 organizations have directly participated in these exercises. More than 50 U.S. and Mexican companies have participated as well. Figure 2 shows the different types of Mexican institutions that have participated in training activities to date.

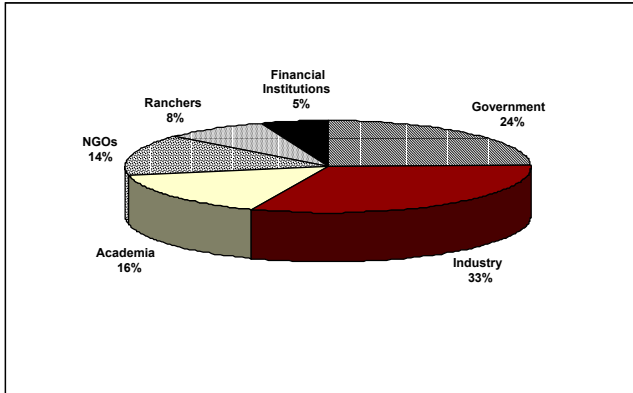


Figure 2. Types of Mexican institutions participating in program training activities.

In some cases, intensive training has been provided to managers of new RE programs in partner organizations. For instance, 14 FIRCO engineers have received intensive, extended training in the U.S. through this program. These engineers are now conducting training of their FIRCO peers in Mexico with Sandia providing a limited support role only. These training activities have led to the development of new training materials, such as a PV water pumping guidebook and an interactive CD-ROM.

It takes time to develop a successful RE development program, and this requires a significant up-front effort, with high impact results only realized later in the program. In essence, the early installations require the greatest efforts. Figure 3 shows the program's cumulative installed capacity projected through the year 2000. At this point, more than 400 independent systems have been installed. The rapid increase in installed capacity throughout the life of the program has been due mainly to the increased ability of partners to implement projects, as well as the increased demand brought on by the visibility of early projects. Installed capacity is ramping up as the program moves from pilot project implementation to large-scale replication.

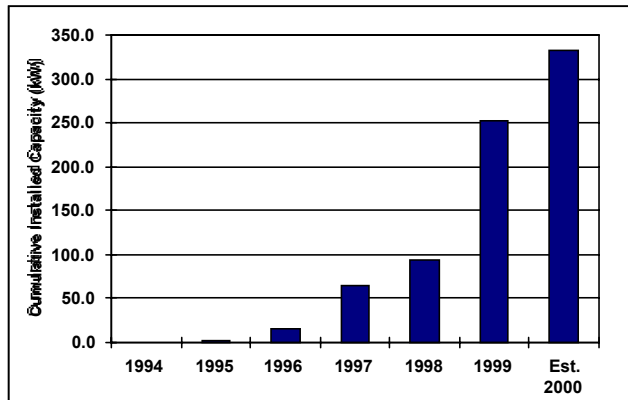


Figure 3. Cumulative installed capacity (kW) of renewable energy projects through the Mexico Program.

MEETING END-USER NEEDS

In the course of implementing projects through the Mexico RE Program, it has been important to assure that the expectations of the end-users are reasonable and that these expectations are met. Quite simply, end-users want quality systems that are reliable and that function properly. End-users often lack a clear understanding of the costs, benefits, and uses of RETs. Unfavorable perceptions of the quality and capabilities of RETs can spread quickly within and

among rural communities, seriously impairing the growth of free markets, as has been observed both in Mexico and in Brazil [3]. Clear and reasonable end-user expectations are essential for the steady growth of sustainable markets. Inexpensive sub-standard installations prone to failure do not meet end-users long-term objectives; they want high reliability with minimal maintenance.

To help build and clarify expectations of the users of RETs, the Sandia team conducts various promotional activities related to the technologies. Pamphlets and posters have been designed and distributed that provide explanations of RE benefits. The team has also assisted partner organizations with trade shows, agricultural fairs, and expositions – often accompanied by operational RE installations. Promotional materials often include the results of economic and technical analyses showing the benefits of RETs in specific applications. For example, Figure 4 shows the results of a comparison of the lifetime costs of a PV system that replaced a diesel-powered pump in the state of Baja California Sur. Although the PV system has a higher initial cost, the total cost of maintaining and operating the system is lower than the diesel after 6 years. Other installed systems have realized full payback in less than two years. These types of real-world examples allow potential buyers to make an informed decision about purchasing PV to replace their conventional systems.

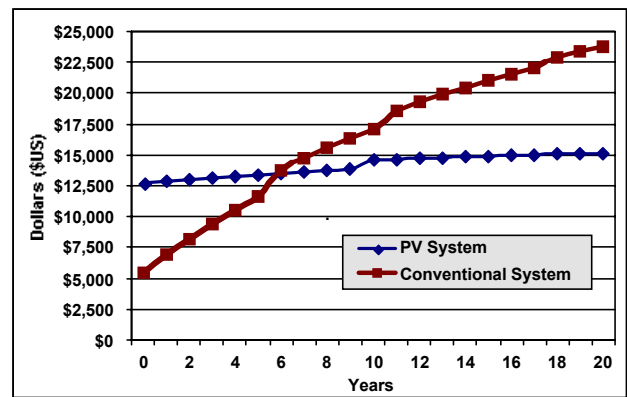


Figure 4. Life-cycle cost analysis of a PV versus diesel water pumping system at Rancho Agua Blanca, Baja California Sur.

The Sandia team works with suppliers to assure that end-users receive proper training. This training takes place during all phases of the project implementation cycle. Ranchers and other interested parties are invited to attend intensive multi-day program seminars that cover both technical and institutional aspects of project implementation. While in the field developing projects, Sandia and its partners work to assure that potential recipients gain an understanding of the costs and capabilities of RETs. As part of the procurement process, end-user training in the O&M of installed systems is required by all suppliers, along with the provision of an owner's manuals. When a need for follow-on training is identified, the Sandia team will organize workshops for users, as in the case of protected-areas installations. For more sophisticated installations (e.g., hybrids), simple and clear maintenance logs are provided and placed with the systems.

Indicators such as market growth and increased willingness to pay are used to assess customer satisfaction for RE systems. Figure 3 attests to the market growth brought on by increased customer satisfaction and demand for systems. Figure 5 shows the trend of in-country cost share for the systems procured through the program. On a program-wide scale, the in-country cost share, which is a combination of partner organization and end-user contributions, has been increasing over the life of the program, except between 1995

and 1996, when Mexico was still in the grips of the peso crisis. In the states of Baja California Sur and Chihuahua, where the program has been very active for several years, the results show steadily increasing in-country cost share.

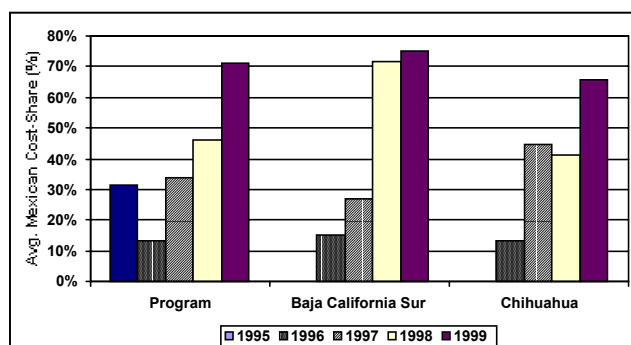


Figure 5. In-country contributions for program-sponsored PV water pumping installations (Chih data includes all system types).

End-user surveys can provide valuable feedback in regard to customer expectations, usage patterns, and overall satisfaction. As part of the program monitoring activities, the Sandia team has conducted surveys of end-users of water pumping systems, home lighting systems, and many of the systems that were installed through protected areas activities. The information gained thus far shows high levels of satisfaction with these new systems. The key to this satisfaction is the installation of good quality systems that work for many years.

For PV water pumping systems, the program team has interviewed approximately 20% of the system owners, with some systems over five years old now. All said that they decided to purchase their systems because they believed that the systems would require less effort to operate and maintain, and because the Sandia program was sharing the initial costs. More than 80% of the owners surveyed rated their PV systems as "excellent" in terms of convenience, reliability, and performance. The remainder reported rated their systems as "good" in these areas. Ninety-two percent of respondents said that they would buy another system or recommend purchase to a friend or family member. Figure 6 illustrates some of the perceived socio-economic benefits that these system owners are reporting. Among the comments received were that ranchers and small farmers have noted increases in the production of forage, vegetables, seeds, and more free time to spend with their families.

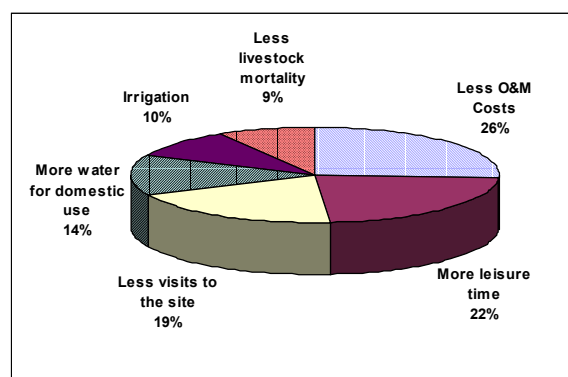


Figure 6. Perceived socio-economic benefits of end-users of PV water pumping systems.

Surveys were also conducted with some of the 125 owners in Moris of the PV home lighting systems financed with the Chihuahua

Renewable Energy Working Group. Seven months after installation, 95% rated their PV systems as reliable, and 84% did not find their systems as expensive (owners only paid 33% of total system costs). Note that no system failures have been reported for all of the 145 Sandia sponsored PV lighting systems in Chihuahua to date.

The positive customer satisfaction is important and allows the private sector to build on program successes. For instance, in the state of Chiapas, the Sandia team worked with local partners to install 10 PV systems at a training center and at ranger stations in the El Ocote Reserve. In the past, residents of the surrounding communities had unfavorable experiences with poorly designed and installed substandard PV lighting systems. However, upon seeing the performance and quality of the Sandia program installations, they soon elected to use their limited municipal funds to support the purchase of more than 140 quality home lighting systems. Sandia's local partners used their newly acquired skills to provide technical assistance to the local residents as they worked with local suppliers. This example is being repeated throughout Mexico as program success grows.

STRENGTHENING RE MARKETS

One of the primary strengths of the Sandia program has been its focus on working closely with suppliers of RE systems to ensure the technical quality and longevity of systems installed through the program. Industry coordination includes training for system suppliers, technical assistance in design and installation, feedback from installed systems monitoring, and testing of new system configurations. More than 50 U.S. and Mexican suppliers have participated in the program. Through diligent work with suppliers and manufacturers, the Sandia program has a success rate of over 98% of installed systems still functioning up to five years after installation (the few non-functioning systems have suffered from theft for the most part).

This work with suppliers has led to improved product quality and lower prices. Figure 7 illustrates the trend in prices of PV water pumping systems to the end-user in the states of Baja California Sur and Chihuahua, where Sandia has worked longest. Trends are shown in terms of cost per Watt for installed systems.

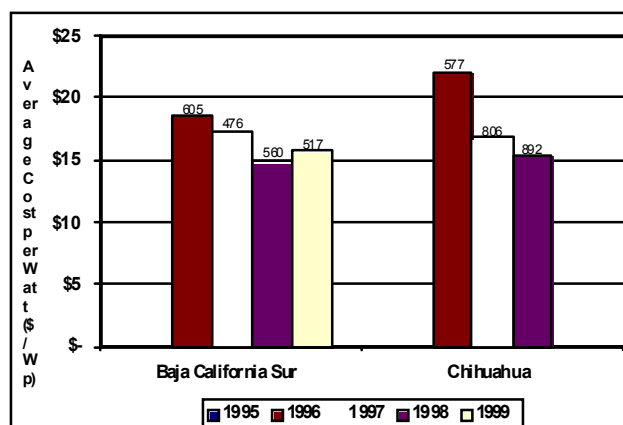


Figure 7. Decreasing price per Watt by year and average systems size of Mexico Program PV water pumping systems.

Since the start of the program, Sandia has enforced the use of a minimum set of technical specifications based on the existing Mexican electric code for all systems. In addition to prescribing the quality of installed systems, these specifications also require guarantees for all components. Perhaps the most innovative part of the Sandia specifications is that they also require suppliers to provide warranties on installed systems, in addition to components. This

means that, for a specified amount of time, generally between one and three years, the supplier is responsible for any system failures. These system warranties are included in the purchase price of the systems. As suppliers learn to install higher quality systems and gain confidence in their technical abilities, the cost of these warranties will decline.

Another area of collaboration between the Sandia team and the suppliers of systems is in the area of training. Almost all program-related technical workshops include hands-on activities, usually with participants involved in the installation of a RE system. In these cases, the supplier is considered part of the training team, and is required to provide instruction and materials for all participants. In most cases, other system suppliers are in the audience. Other training activities focus on specific needs of the industry. Topics covered have included aspects of system design, the development of effective bid packages, and the development of an effective distributor network. In several cases, the Sandia team has partnered with suppliers on the establishment and execution of training strategies as they work to build supply networks throughout Mexico.

The Mexican and U.S. RE industries benefit from Sandia feedback related to installed systems, and in the development of new system configurations. In all cases, technical information is provided to industry regarding the performance of their systems, allowing real-time improvement of both component design and system integration.

NEW OPPORTUNITIES

The Mexico RE Program is dynamic and in continual transition. According to the original program plan, funds that were previously available to share the cost of pilot systems are no longer available, and the program is moving fully into the "replication and institutionalization" phase. The importance of the partnerships upon which the program has based its successes will continue to grow.

Several new opportunities are being developed through the program with the goal of replicating the successes to date. To effectively obtain this goal, the program team will work closely with partners to help them further increase their abilities to effectively develop RE components in their programs. Some of these opportunities are presented here.

FIRCO/GEF program. Based on the successes of their partnership with Sandia, FIRCO (on behalf of the Mexican Secretariat of Agriculture) is initiating the first-ever Global Environment Facility program focused on agricultural applications of RE. This 5-year program will have an overall investment of \$US31 million in equipment, resulting in the installation of over 1,200 PV and 55 wind water pumping systems. The program plan also includes the development of new applications, such as milk tank cooling, and innovative vendor financing programs.

Secretariat of Energy/World Bank rural electrification. The Sandia team, principally Winrock International, is assisting the World Bank and the Mexican Secretariat of Energy (SE) as they develop a pilot off-grid rural electrification program that will include innovative delivery and cost recovery mechanisms and the integration of community projects (i.e., schools, clinics, homes, etc). The plan is to build on RE development successes now realized in the states of Chihuahua and Quintana Roo.

Secretariat of Environment, Natural Resources, and Fisheries (SEMARNAP). SEMARNAP manages all reserves in Mexico, and has recently dramatically increased its budget for management activities, both in terms of personnel and equipment. They are interested in replicating the protected-areas successes of the Sandia team in other reserves in Mexico.

Increased private sector interest. The success of the Sandia program is also replicated through private sector sales to end-users. Although difficult to monitor, the program team is collecting data that shows increases in private sector sales in Baja California Sur, Chihuahua, Sonora, Chiapas, and Quintana Roo, where the program has been operating for several years now.

Other new government and NGO partnerships. Sandia is developing new strategic partnerships. Activities are underway with the Secretariat of Public Education (SEP) for their distance education program. Presently, SEP has over 500 PV-powered rural schools, with more than 1,000 others that are not electrified. Sandia is providing technical assistance in reviewing existing system configurations for improvement. The Sandia team is also helping the Mexican Rural Development Foundation (FMDR) to build capacity to implement RETs in their programs.

New applications. The Sandia team is building partnerships to establish activities with new applications and technologies, including solar water heating, water purification, milk cooling, battery-free refrigeration, and PV ice-making as in Figure 8.



Figure 8. Sandia, SWTDI, and NYSERDA worked with SunWize and ENSO to successfully install the world's first PV ice-maker for the fishermen of Chorreras, Chihuahua in 1999.

Figure 9 is a projection through 2005 of the installed capacity of the Sandia program, the FIRCO program, and private sector replication. This anticipated growth is the result not only of the efforts of the Sandia team, but also of other organizations and suppliers who have improved expectations and quality of projects.

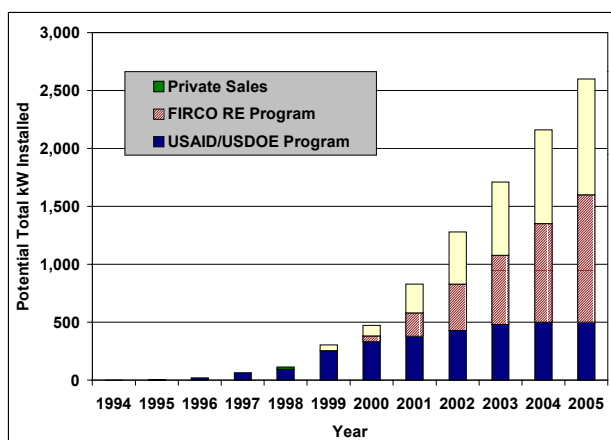


Figure 9: Projected installed capacity (kW) in Mexico with support from the Sandia program.

NEW CHALLENGES

The opportunities discussed above bring with them several challenges for the continued success of the program and its follow-on activities. Some of these challenges are presented here.

- *Adherence to technical quality standards.* The true measure of success for this program is the replication of *high-quality* RE systems. Through the adoption of technical specifications based on the Mexican electrical code and warranties, the Sandia program is introducing a new level of quality in terms of expectations and delivery capabilities. As the number of installations continues to increase, it will be increasingly difficult to ensure that these quality standards are being met directly by the Sandia team and these responsibilities will increasingly fall on partner organizations trained by Sandia.
- *Building a strong supplier network.* To meet the demands of these new implementation programs, system integrators in Mexico will need to strengthen their supply and maintenance networks. It is likely that new partnerships among companies will be needed, and that technicians will need to be identified and trained throughout remote areas. Program implementers will need to work with suppliers to meet the increasing demands. In the new FIRCO/GEF program, for instance, a component of the program is structured toward industry strengthening.
- *Training and capacity building on a larger scale.* Much broader institutional capacity will be required within participating organizations to effectively manage the implementation of RE projects. This training will have to be done at different levels and will need to reach out to different audiences. Sandia is working with its in-country partners, namely FIRCO and the National Solar Energy Association (ANES), to develop a national RE training strategy designed to meet the various growing needs for training throughout Mexico. FIRCO plans to conduct over 32 training courses between late 2000 to 2001. Other participating institutions are the National Energy Savings Commission (CONAE) and the Energy Research Center of the National Autonomous University (UNAM/CIE).
- *Continuing to foster reasonable end-user expectations.* Ultimately, it is the perceptions and expectations of the end-users of the technologies that will dictate the rate of growth and sustainability of RE markets. Much more promotion is needed for this target audience, and increased visibility of the benefits or RETs. As part of the FIRCO program, promotional materials will be produced, including radio announcements. Activities of this sort will be needed on a broad scale, so potential buyers can be much better informed about the realities of utilizing RETs.
- *Improving end-user and vendor access to financing.* The high initial costs of RETs in comparison to more conventional technologies are still a major barrier to market growth. Fortunately, both the FIRCO program and the proposed Secretariat of Energy programs include components that allow for the implementation of innovative means of financing for both vendors of systems and end-users. The Sandia program is also implementing end-user financing in Chihuahua and is developing a financing activity in Oaxaca as well. The success of this and other related activities will be critical to allow significant growth in the markets for rural applications of RETs, where users often have steady incomes but have very little capital to use for investments.

- *Developing wind markets.* A component focused on the introduction of small wind technologies for productive uses for the Mexico RE Program has been conducted in partnership with the National Renewable Energy Laboratory (NREL). Although 4 projects have been implemented, the development of a sustainable market for small wind has proven to be difficult. First, the wind resource is more localized than the solar resource, making wind project siting more difficult. Second, due to maintenance requirements of rotating wind machinery, there is a need for locally available spare parts and personnel for which an infrastructure does not exist in rural Mexico. As FIRCO works to implement wind projects for the GEF program, a plan is needed that will address these challenges and addresses industry strengthening, training, financing, and establishing a quality standard for wind systems. This plan must focus on developing a sustainable wind industry and not just projects.

CONCLUSIONS

Working closely with its Mexican partners, the Sandia team has made great strides in the development of sustainable markets for RE technologies, principally PV, in rural applications in Mexico. This success is most evident in the agriculture and protected areas sectors, while recent activities are making important impacts in rural electrification. These successes have been achieved through:

- Working with partners to identify and develop RE applications within their existing programs;
- Working closely with suppliers of RE equipment to help them improve their ability to deliver quality systems; and,
- Making sure that end-users understand the technologies and how to properly maintain their systems for maximum benefit.

Through the development of technical specifications, extensive training activities, and the implementation of pilot projects, more suppliers have the ability to design and install long-lasting RE systems. Thus, more end-users have a greater appreciation of the value and capabilities of RETs.

The future brings exciting new opportunities and challenges, as the successes of the Mexico RE Program are replicated in other new programs. The challenges of effectively implementing over 1,300 FIRCO/GEF projects focused on RE for agriculture will require a broad-based collaboration of a variety of public and private organizations. Similarly, as the SE moves toward implementing an innovative rural electrification program, both program implementers and suppliers will need to develop new skills to assure success. These and other challenges will be met through continued collaboration among the various organizations that are involved in building and maintaining sustainable markets for RETs. The outlook is good for the program to meet these new challenges and multiply its success many-fold in the coming years.

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